Clouds, Radiation & Climate

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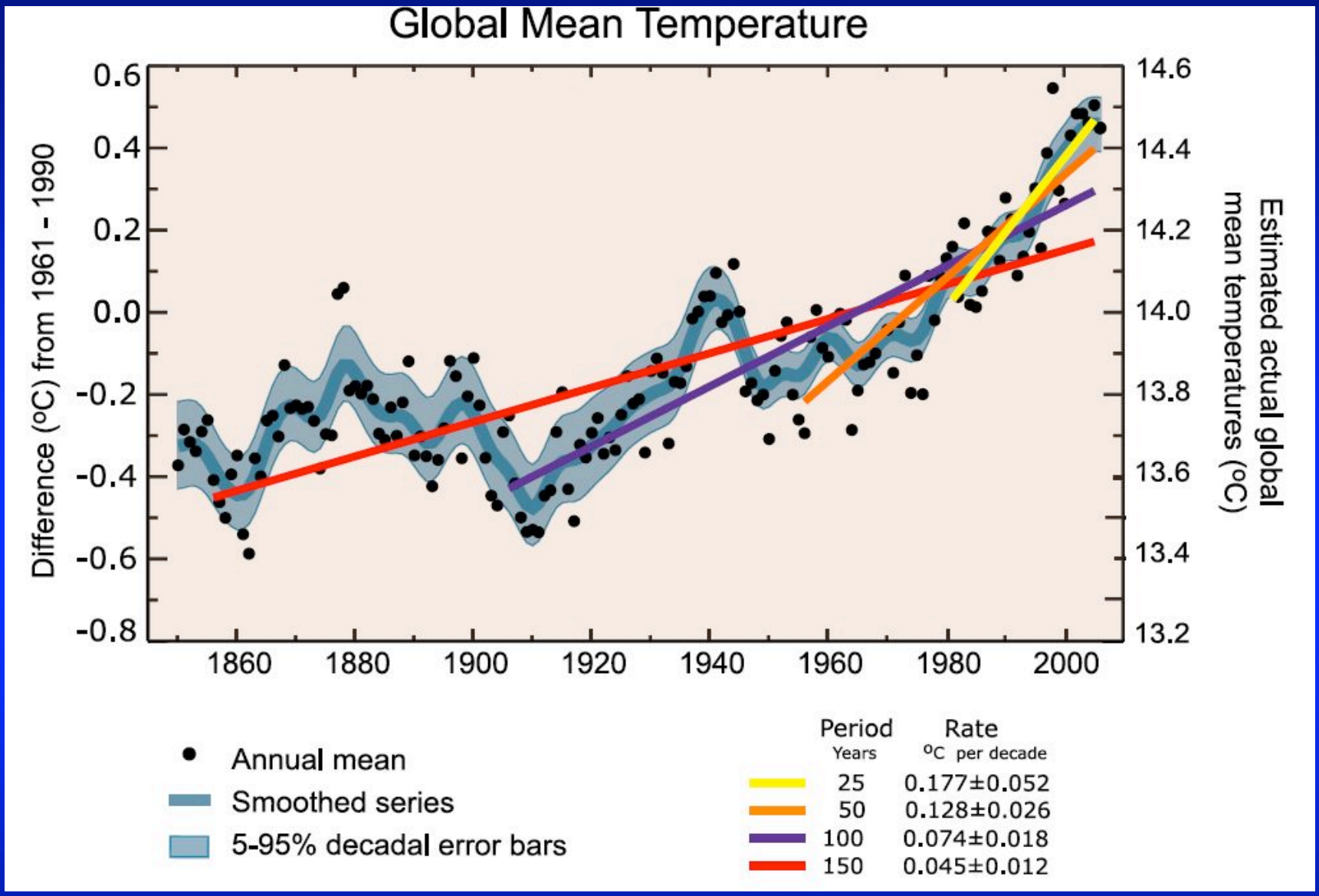
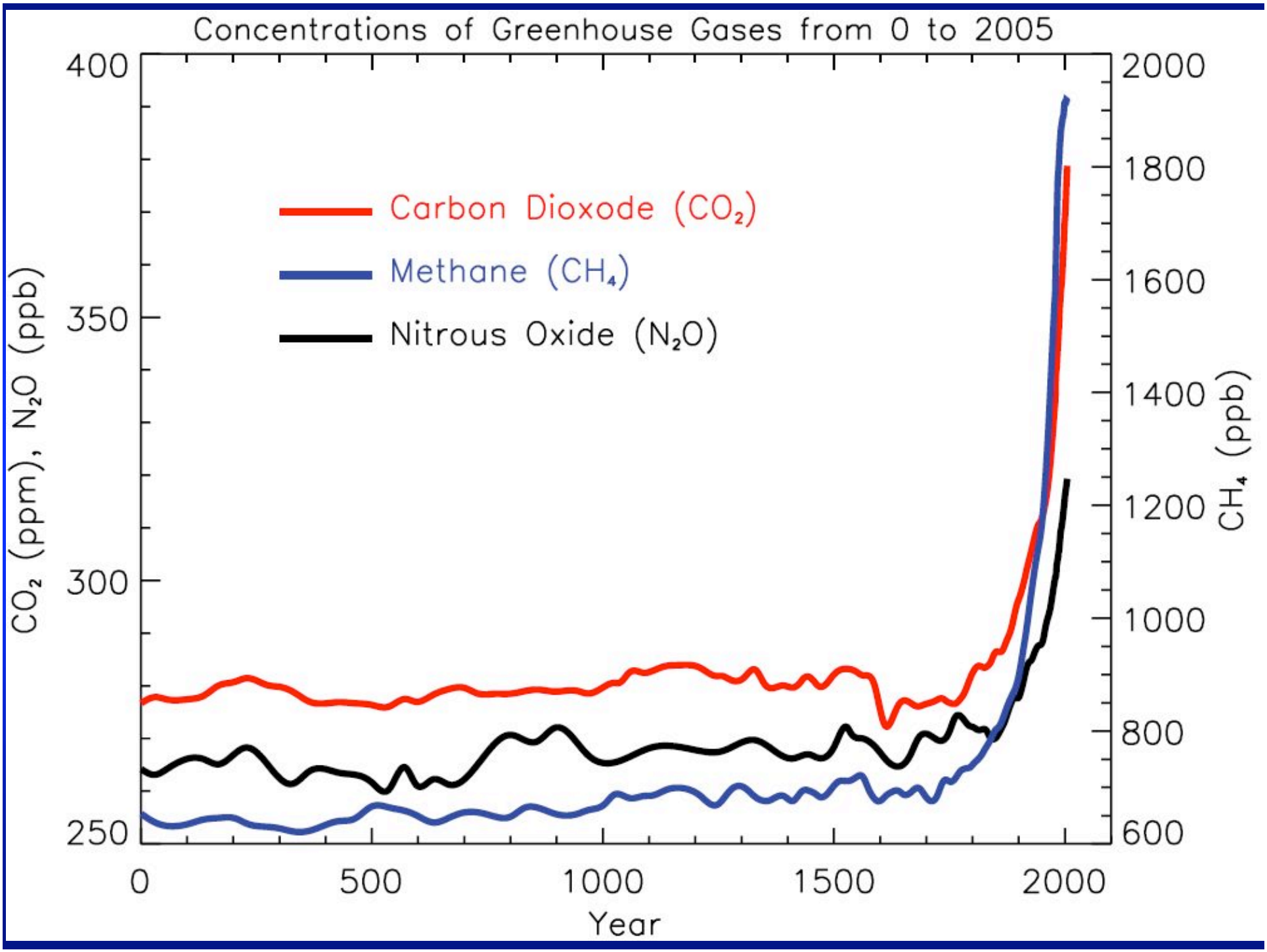


Global Mean Temperature Difference Relative to Present:

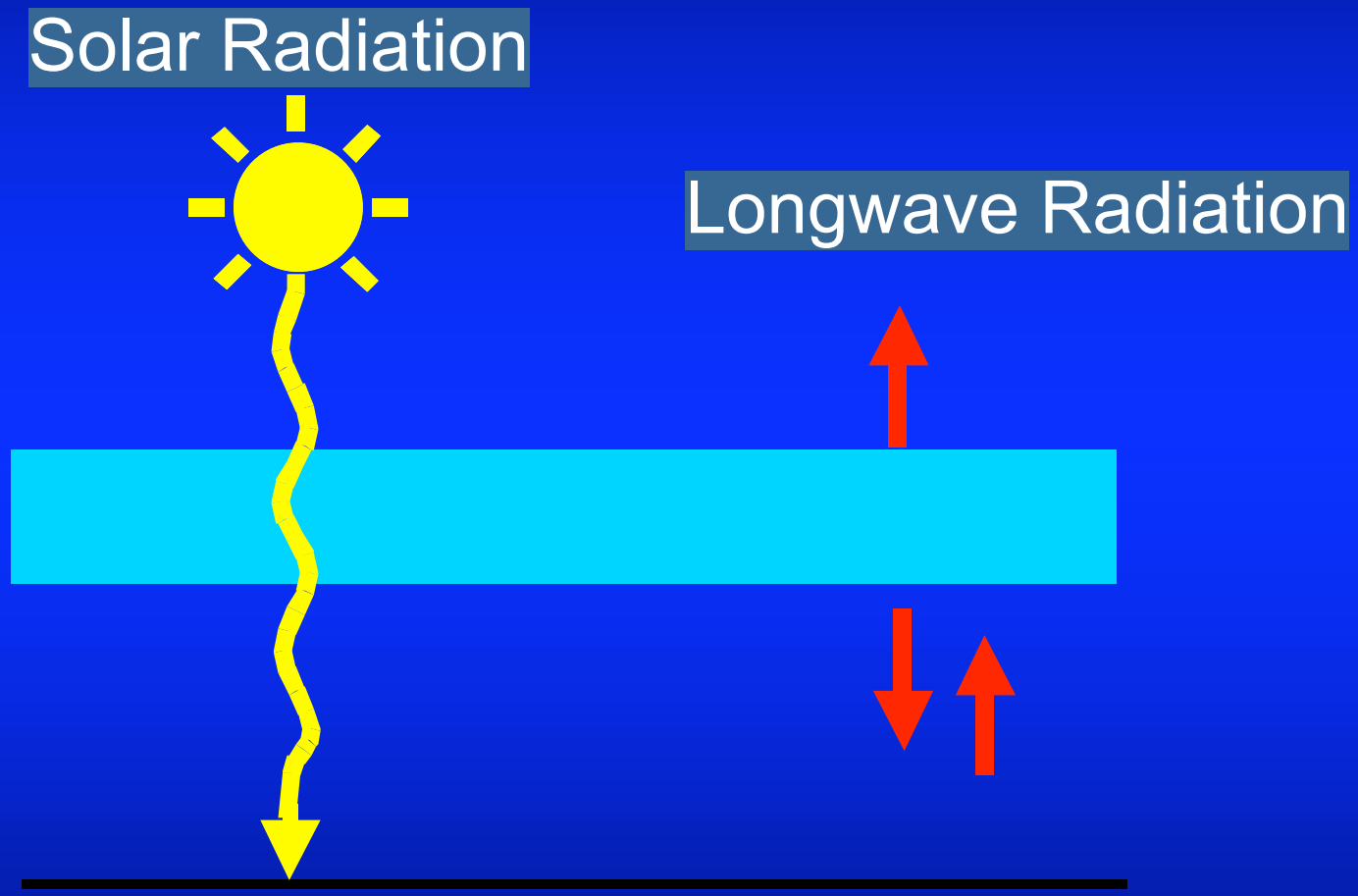
-> 100-years ago: ~0.74ºC cooler

-> Last ice age: ~5ºC cooler

-> Climate model projections (2100): 2ºC - 4.5ºC warmer (1σ)

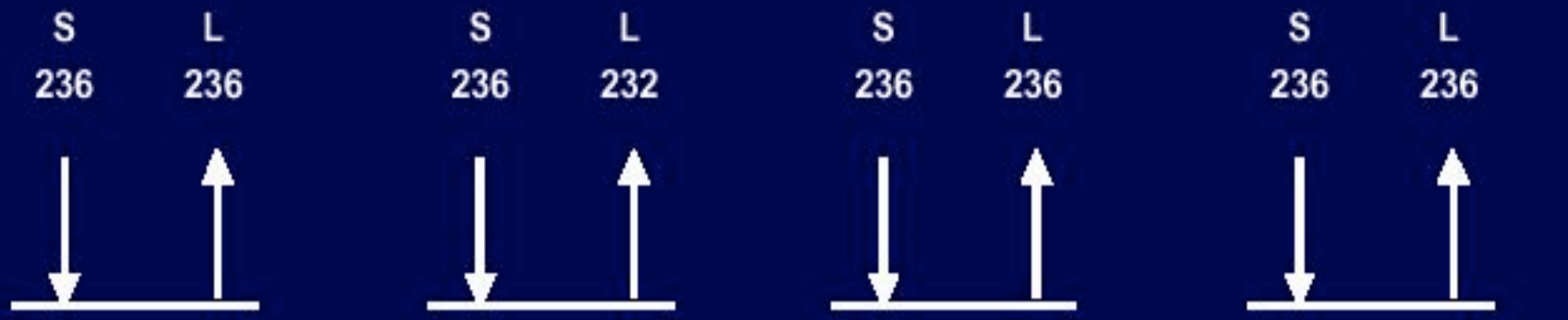

Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
Year
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000

The Greenhouse Effect

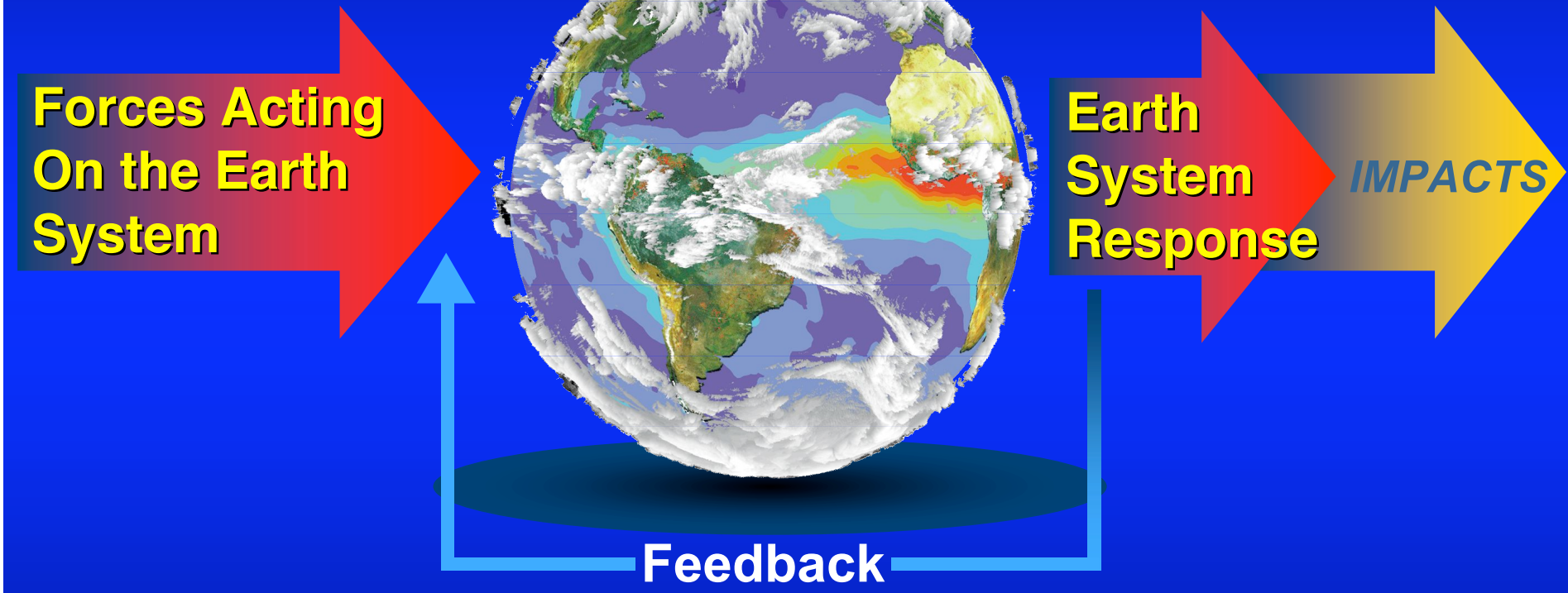


The Enhanced Greenhouse Effect

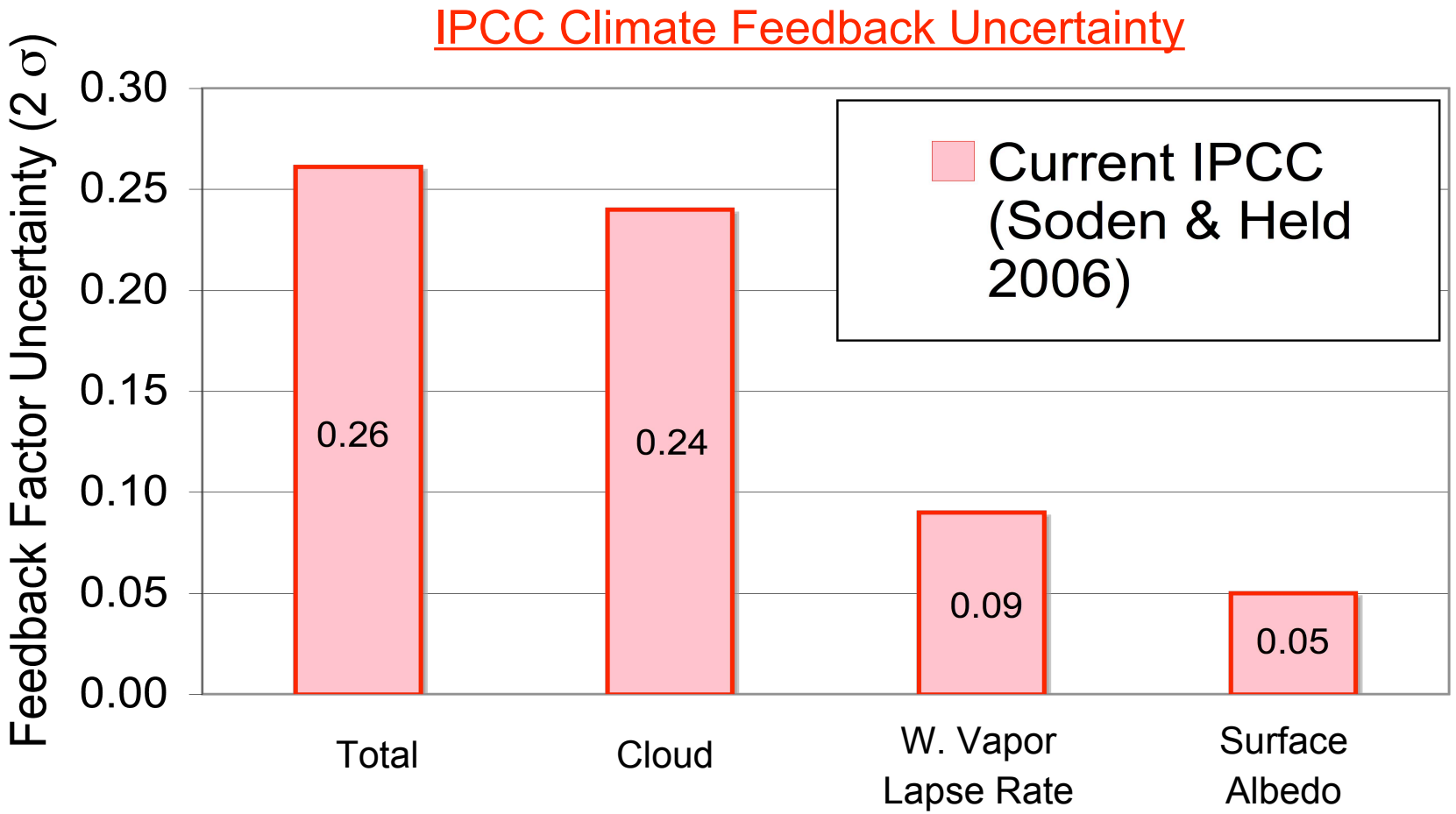
Solar (S) and longwave (L) radiation in Wm^{-2} at the top of the atmosphere



How does the Earth Respond?



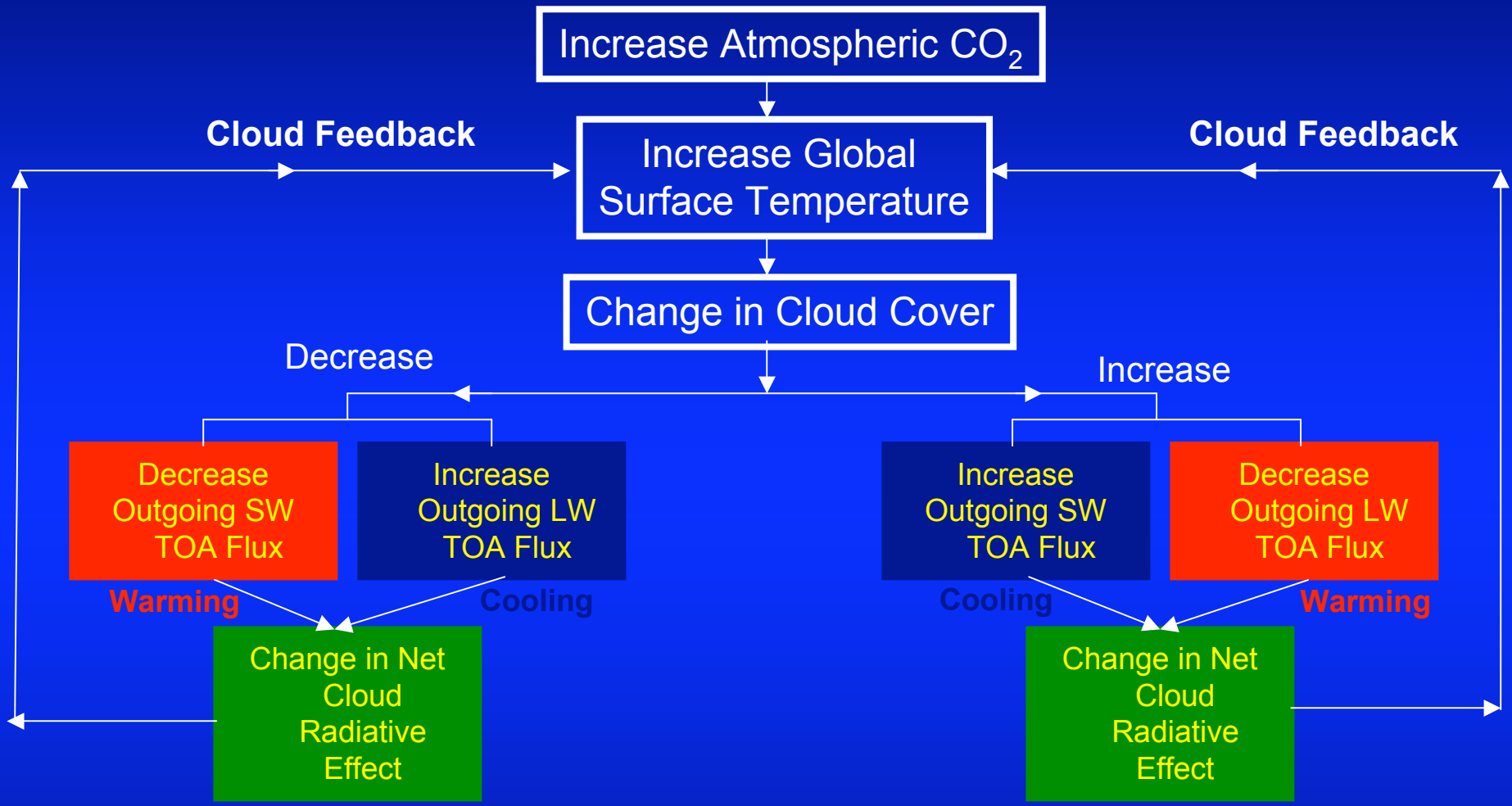
Of the total forcing of the climate system, 40% is due to the direct effect of greenhouse gases and aerosols, and 60% is from feedback effects, such as increasing concentrations of water vapor as temperature rises, cloud changes, etc.



The uncertainty in climate feedback is driven by these three components. The feedback for the climate system is $f = 0.62 \pm 0.26$ (2σ).

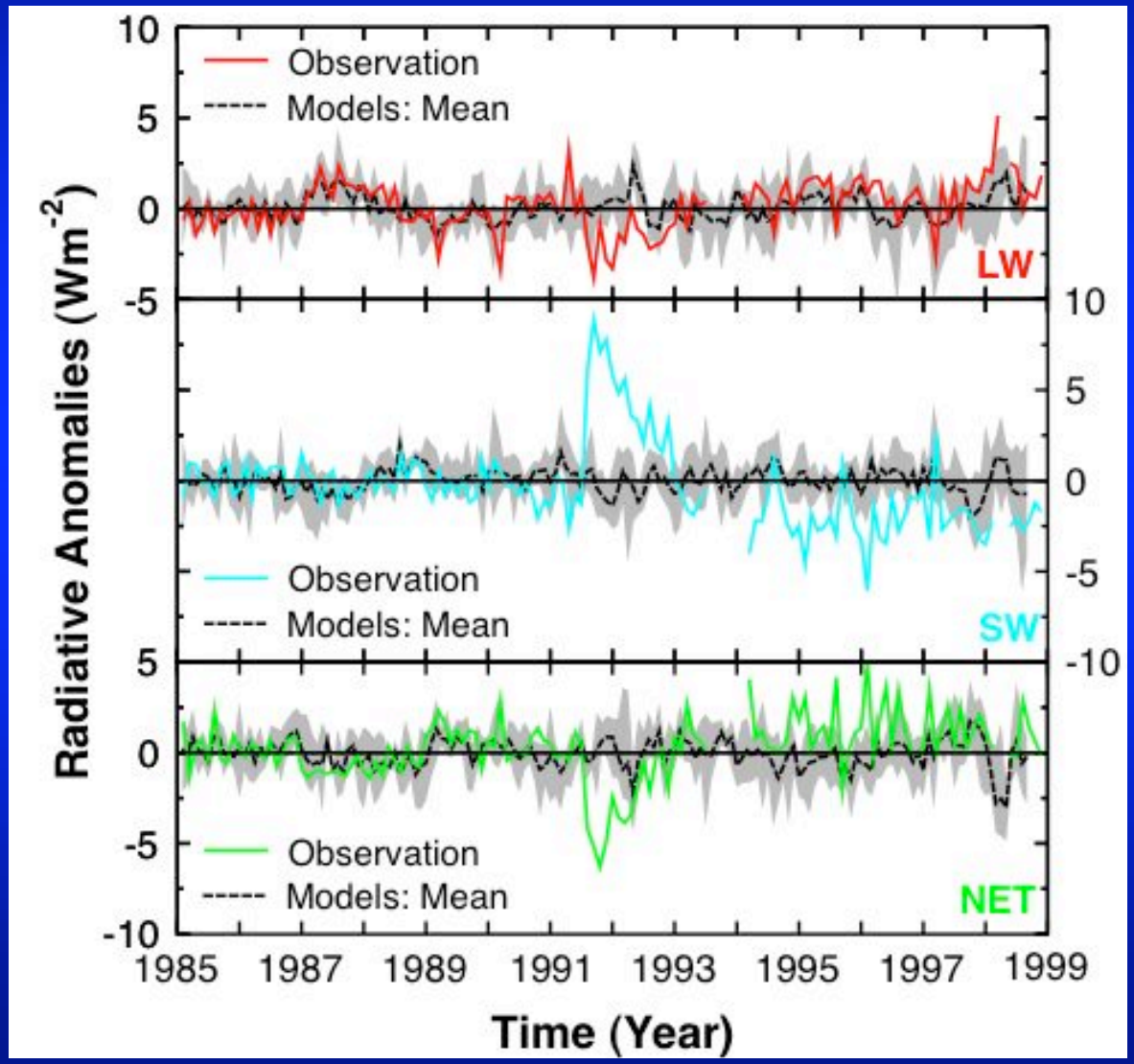
This corresponds to a 2ºC-10ºC range in equilibrium climate sensitivity in response to doubling CO_2.

Cloud Feedback



- ***CERES will observe decadal changes in net cloud radiative effect that will reduce the uncertainty in cloud feedback and therefore climate sensitivity.***

Tropical (20S - 20N) TOA Radiation Anomalies: Observations vs. Climate Models



Edition 3 ERBS

Decadal Changes (1980s to 1990s)

LW: 1.6 Wm^{-2}
SW: -3.1 Wm^{-2}
NET: 1.5 Wm^{-2}

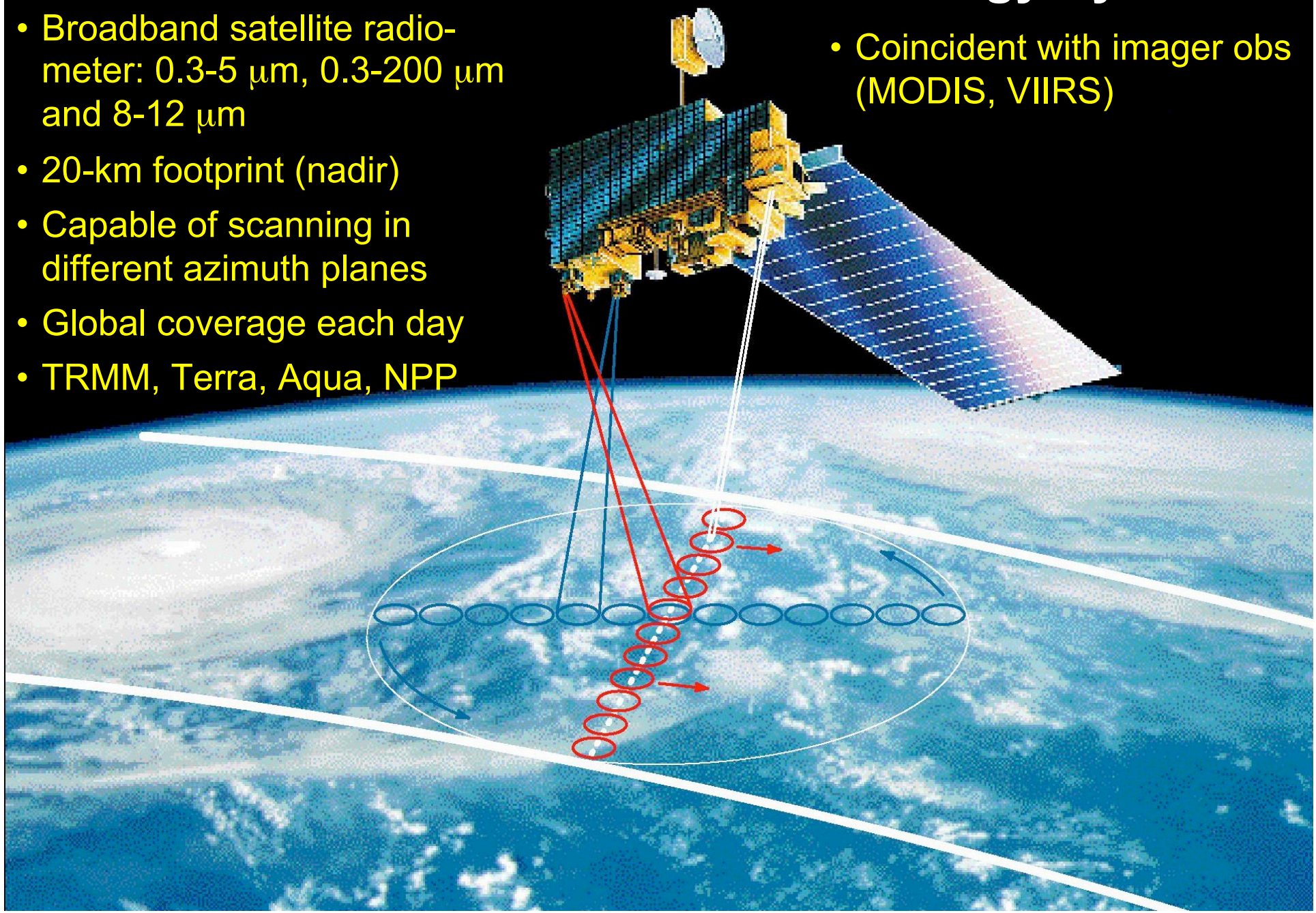
Models less variable than the observations:
- missing feedbacks?
- missing forcings?
- clouds physics?

Wong et al., J. Climate, 2006

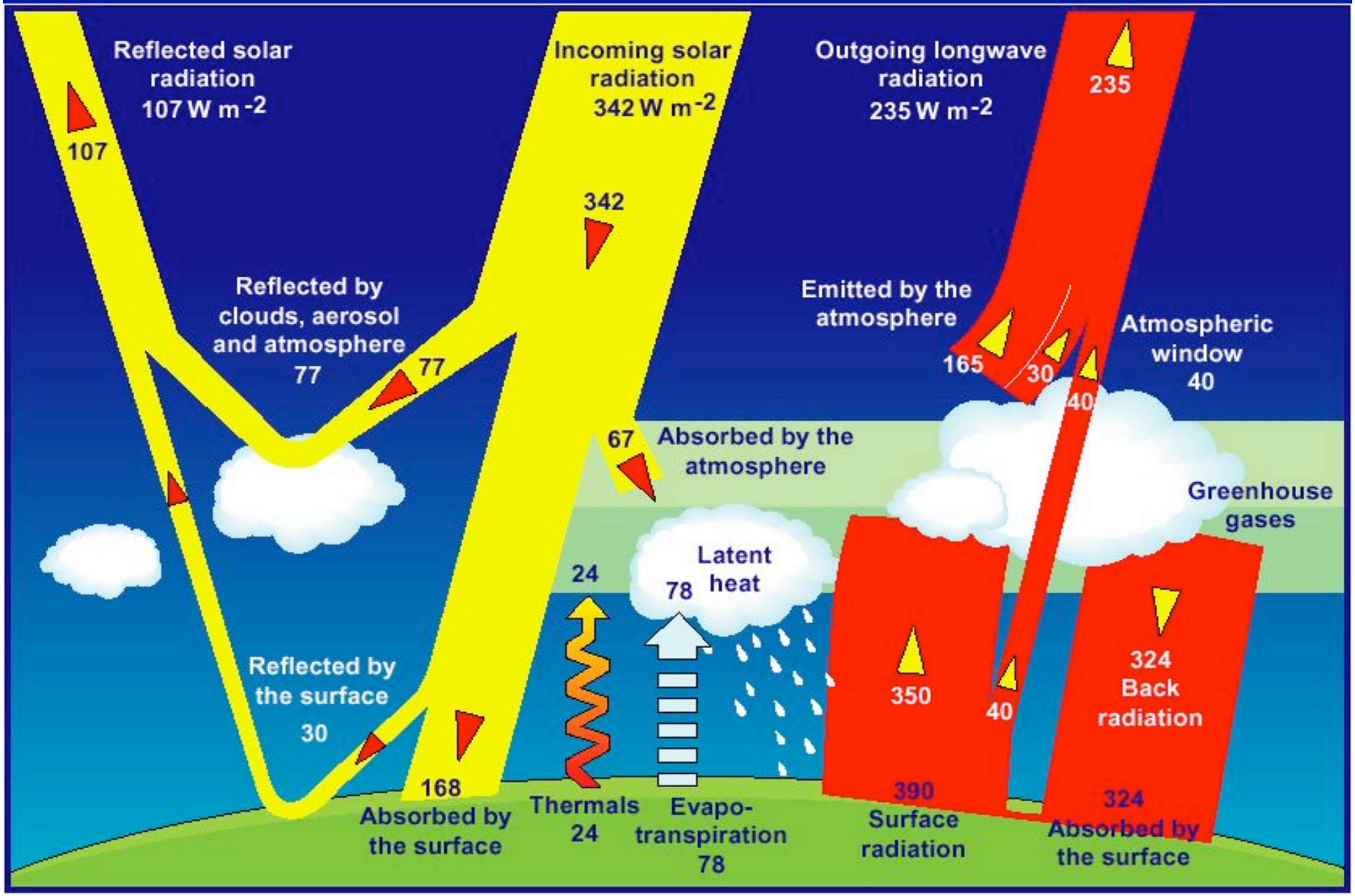
Clouds and the Earth's Radiant Energy System

- Broadband satellite radio-meter: 0.3-5 μm, 0.3-200 μm and 8-12 μm
- 20-km footprint (nadir)
- Capable of scanning in different azimuth planes
- Global coverage each day
- TRMM, Terra, Aqua, NPP

- Coincident with imager obs (MODIS, VIIRS)



Global Radiation Budget



Climate Data Records and CERES

"A time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change"

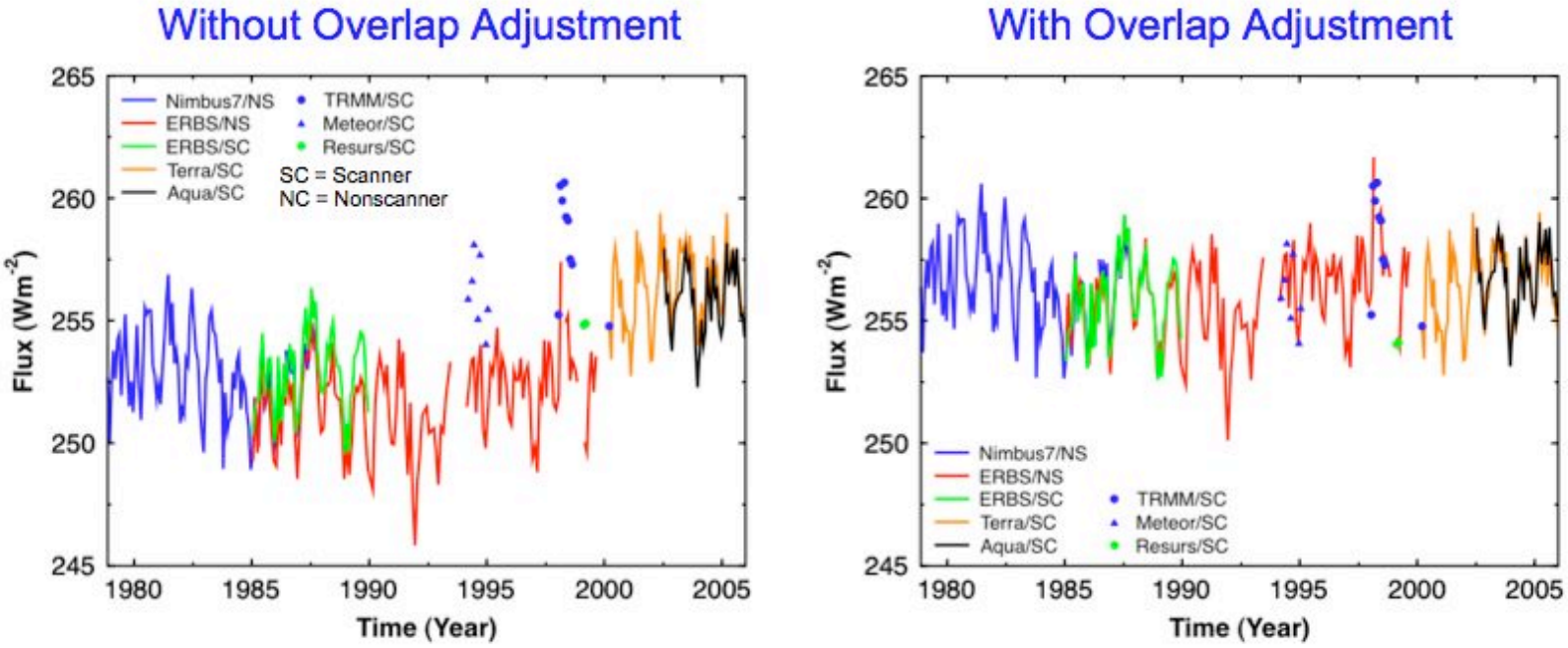
NRC Climate Data Records from Environmental Satellites: Interim Report

- **CERES climate data products are unique in their level of data fusion: 11 instruments on 7 spacecraft all integrated to obtain climate accuracy in top-to-bottom radiative fluxes.**

- **To ensure CERES data products are consistent in time, all algorithms and inputs used to generate CERES data products are "frozen" for the entire length of the record.**
  - **Any major change to either the algorithms/inputs requires a major reprocessing of the entire data record.**

- **CERES data products for CERES TRMM, Terra, Aqua are being processed at the NASA Langley Atmospheric Sciences Data Center.**

Tropical Mean (20°N to 20°S) Outgoing Longwave Radiation

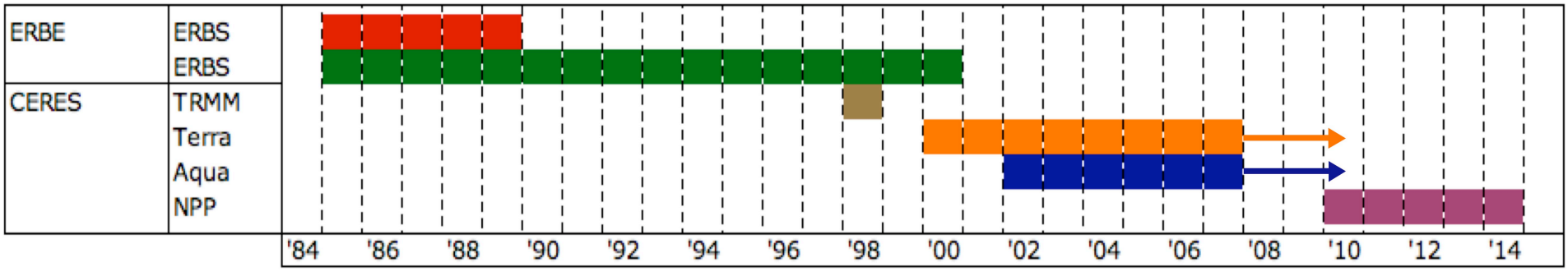


- ***Instrument-to-instrument absolute calibration differences are 1 to 4 Wm^{-2}.***

=>Absolute accuracy alone is insufficient to detect climate change at the 0.6 Wm^{-2} per decade level of anthropogenic radiative forcing by greenhouse gases.

- ***Overlapping observations allows the use of instrument stability instead of absolute accuracy to constrain decadal climate change.***

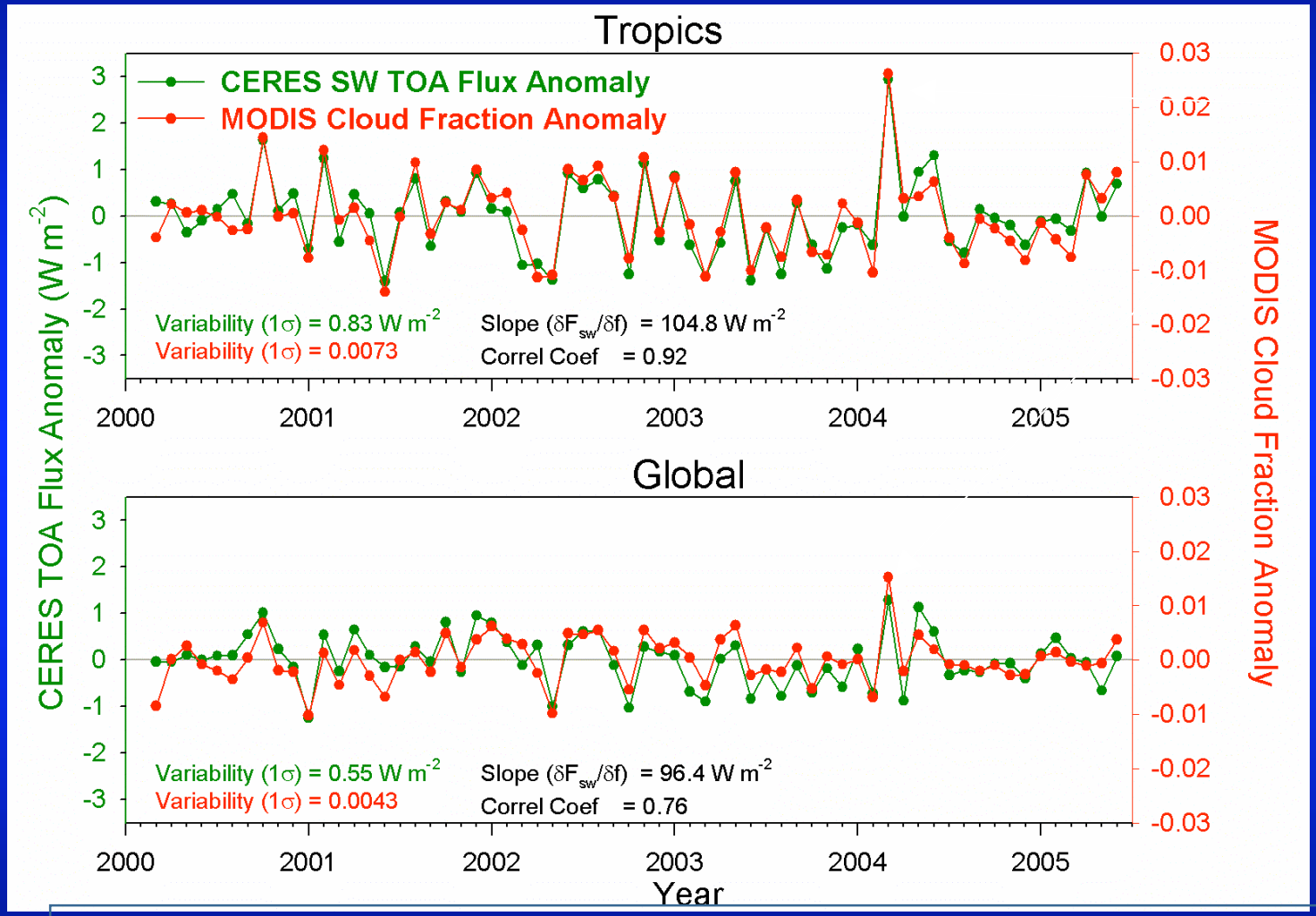
Earth Radiation Budget Measurements at NASA LaRC



CERES Climate Data Record

- **TRMM (1998), Terra (2000-present) & Aqua (2002-present).**
- **The NPOESS Preparatory Project (NPP) in 2010.**
- **Possibly NPOESS C1 in 2014.**

CERES Shortwave TOA Reflected Flux Changes: Ties to Changing Cloud Fraction

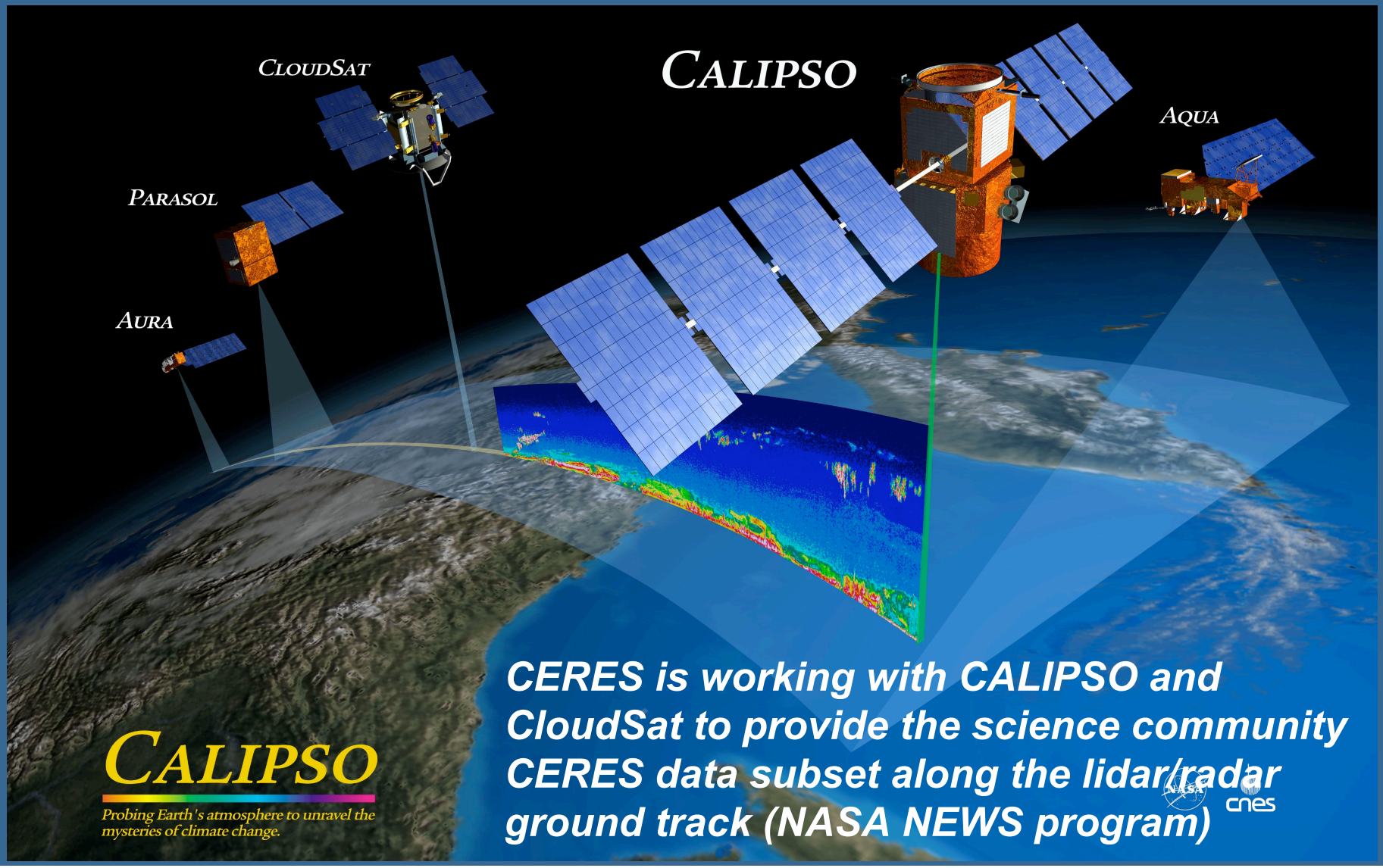


Tropics drive global albedo variations: global is in phase with tropics and 1/2 the magnitude

Cloud fraction variations are the cause (not optical depth)

Unscrambling climate signal cause and effect requires complete parameter set at climate accuracy, e.g. for forcing/response energetics: radiation, aerosol, cloud, land, snow/ice, temperature, humidity, precipitation

"A-Train" Formation for Aerosol and Cloud Vertical Profiles
Atmospheric State => Aerosol/Cloud => Radiative Heating



Conclusions

- Clouds and radiation play a critical role in climate.
- The largest uncertainty in global climate sensitivity over the next century is cloud feedback.
- NASA global climate data records of the Earth's radiation budget, cloud and aerosol properties are critical to:
  - Understanding climate variability at decadal time scales.
  - Constraining cloud feedback and hence climate sensitivity in climate models.
- Continuous overlapping broadband radiation budget data are critical to determination of cloud feedback over the next 2 decades.